Original Contribution

Studies on the extended Techa river cohort: cancer risk estimation

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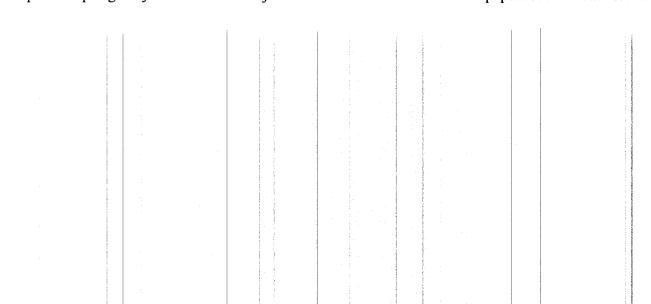   Phone: +81-82-2613131
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Background

Initial population-based studies of riverside residents were begun in the late 1950s and in 1967 a systematic effort was undertaken to develop a well-defined fixed cohort of Techa river residents, to carry out ongoing mortality and (limited) clinical follow-up of this cohort, and to provide individualized dose estimates for cohort members [1]. Over the past decade, extensive efforts have been made to refine the cohort definition and improve both the follow-up and dosimetry data.

Aims of the study

Analyses of the Techa river cohort can provide useful quantitative estimates of the effects of low dose rate, chronic external and internal exposures on cancer mortality and incidence and non-cancer mortality rates. These risk estimates complement quantitative risk estimates for acute exposures based on the atomic bomb survivors and chronic exposure risk estimates from worker studies, including Mayak workers and other groups with occupational radiation exposures. As the dosimetry and follow-up are refined it may also be possible to gain useful insights into risks associated with ^{90}Sr exposures.

Description of the cohort

As originally defined this cohort included about 26,500 people born before 1950 who lived in riverside villages during the period of maximal releases (1950-1952). Over the years, an additional cohort of about 5,000 people born prior to 1950 who came to live in riverside villages between 1953 and 1960 has been identified ("late entrants"). In 1998, these two groups were merged to form the Extended Techa River Cohort (ETRC), which is the basis of current dosimetry, follow-up, and risk estimation efforts. As originally defined, the ETRC roster included records for 31,234 individuals. However, recent (continuing) efforts have identified duplicate records (due primarily to marriage-related name changes) and individuals with incomplete or inaccurate residence histories who are ineligible for inclusion in the cohort. As of September 2001, the ETRC includes 30,136 people of whom 25,183 are members of the original cohort and 4,953 are late entrants. The ETRC includes men and women from both European (Slavic) and Asiatic (Tartar and Bashkir) ethnic groups with a broad range of ages at first exposure. The lower portion of Table 1 contains statistics that summarize the distribution of sex, ethnicity, and age at first exposure in subsets of the ETRC defined by migration status (discussed below).

Table 1. Mortality follow-up and demographic characteristics of the extended Techa river cohort, 1950-1995

Extended catchment area				
Follow-up status	Original catchment area	Local migrants[a]	Distal migrants	Total
Alive on January 1, 1996	6,670	3,521	1,437	11,628
Dead	11,387	1,434	660	13,658
DC available	10,006	1,219	107	11,332
No DC information	1,381	215	553	2,326
Lost to follow-up	2,428	781	1,818	4,850
Total	20,485	5,736	3,915	30,136
% Female	58%	58%	57%	58%
%Tartar/Bashkir	23%	18%	8%	20%
% Late entrants	16%	19%	15%	16%
Age in 1950 (years)				
0-7	2,107	1,365	987	4,459
8-15	3,264	1,585	1,125	5,974
16-29	5,373	1,519	1,038	7,930
30-104	9,741	1,267	765	11,773
Mean	31.9	19.3	18.2	27.7

[a]Local migrants are cohort members who moved from the original catchment area to other parts of Chelyabinsk or Kurgan Oblasts.

Mortality follow-up is based on queries sent to regional address bureaus and contacts with cohort members by URCRM (Urals Research Center for Radiation Medicine) staff either at the URCRM clinic

in Chelyabinsk or in villages in the original catchment area (which includes five local administrative districts, raions, on the Techa river and two raions to which many riverside residents were evacuated). Information received from the address bureau queries allows determination of a cohort member's vital status or relocation within the last 6 years. For deaths, the address bureau query response contains information that makes it possible, in most cases, to obtain a copy of the death certificate for use in coding the cause of death. In some cases only anecdotal evidence of death is available (usually based on reports from next-of-kin). In these cases, the fact of death is noted together with an approximate date of death, but the cause of death is recorded as unknown. A significant portion of the ETRC members is known to have moved from the original catchment area. Typically these migrants have moved to nearby major cities (Chelyabinsk, Kurgan, or Ekaterinburg) or other areas within Chelyabinsk, Kurgan, or Sverdlovsk oblasts, but some have moved to more distant areas. As a result of recent improvements in the quality of follow-up, analyses will make use of an extended catchment area that includes people who have moved from the original catchment area to other districts in either Chelyabinsk or Kurgan oblasts. The upper portion of Table 1 presents a summary of the ETRC follow-up status for the period from 1950 through the end of 1995.

People are treated as lost to follow-up at the date of migration from the extended catchment area or if they were last known to be alive prior to January 1, 1996. The proportion lost to follow-up and the proportion of deaths for which death certificates are unavailable is lowest for cohort members who remained in the original catchment area but only slightly higher for those who have moved to other areas in the Chelyabinsk or Kurgan oblasts ("local migrants"). However, follow-up quality is considerably worse for distal migrants than for the other two groups. These figures represent a considerable improvement in the quality and completeness of the mortality follow-up since the late 1980s [2].

Over the years various dosimetric systems have been used to compute individual dose estimates for members of the cohort. These were originally based on poorly characterized source terms, limited environmental measurement data, and measurements of ^{90}Sr body-burdens derived initially from measurements of teeth and, since 1974, on whole body counter measurements [3] carried out on more than 14,000 cohort members. A continuing effort to improve and refine dose estimates for ETRC members was begun in the mid-1990s. These efforts have resulted in a new dosimetry system [4]. Individual TRDS-2000 internal doses for GI tract for the upper Techa residents are higher than previously estimated, due to the inclusion of short-lived radionuclides. The external doses are considerably lower than previously estimated, due to more realistic assessments of living conditions. Additional details on the dosimetry for the ETRC are given in a companion paper in this volume [5]. Table 2 provides summary information on the distributions of "old" (similar to those that have been used in published risk analyses [1, 2, 6]) and "new" (TRDS-2000) bone marrow and stomach dose estimates. Risk analyses based on the TRDS-2000 estimates are now in progress and will be presented elsewhere.

Table 2. Summary of dose distributions for members of the extended Techa river cohort

| | Old dosimetry system[a] [mSv] | | | |
| | Soft tissue | | Bone marrow | |
	Original cohort	Late entrants	Original cohort	Late entrants
Mean	99	8	405	12
Median	17	2	267	4
Upper quartile	40	5	530	10
Max.	1177	190	2164	913

	TRDS2000 [mSv]			
	Original cohort	Late entrants	Original cohort	Late entrants
Mean	35	3	353	6
Median	7	0.6	253	3
Upper quartile	22	1	476	7
Max.	456	82	2021	104

[a]These value are based on the TRDS-96 system, TRDS-96-based estimates have not been use as the basis of any published risk estimates, but the dose estimates are quite similar to estimates that were used in earlier publications.

Major results

Published risk analyses have focused on the Original Techa River Cohort (OTRC). The analyses presented by Kossenko et al. [2] consider follow-up through 1989 and provide clear evidence of statistically significant dose-response relationships for both solid cancers as a group and leukemia, with no evidence of statistically significant non-linearity in the dose-response functions. Due to incomplete follow-up data and the limitations of the "old" dosimetry system, that paper did not explicitly provide estimates of the risks per unit dose. However, the results suggest that about 3% of the 969 solid cancer deaths and 40% of the 50 leukemia deaths are associated with the radiation exposure. Based on similar dose estimates, Kossenko [6] reported the excess relative risk per Sv to be 0.65 (95%, CI: 0.3; 1.0) for solid cancers and the excess rate for leukemia to be 0.85 excess cases per 10,000 person-year Gy (95%, CI :0.2; 1.5) for follow-up through 1982. Solid cancer excess rate estimates have also been noted in several papers, however, these are certainly underestimates since they do not allow for the relatively large percentage of deaths of unknown cause nor for temporal trends in the excess rates.

Problems, limitations, solutions

All of the TRC analyses published to date have been based on incomplete follow-up. About 50% of the cohort was lost to follow-up (23% due to migration and 35% among people thought to be in the original catchment area). Furthermore, the cause of death was unknown for 30% of the deaths. As indicated in Table 1, recent efforts to improve and extend the mortality follow-up in this cohort have led to substantial reductions in both the percentage of deaths for which the cause is unknown (currently about 17%), the proportion of the population that is lost to follow-up (about 16% of the full cohort including 9% who are lost due to migration). In the future it will probably be possible to include additional local migrants.

The development and validation of a system to produce unbiased individual dose estimates is one of the biggest challenges in working with the ETRC data. The dosimetry system is being improved through a continuing program of in-situ environmental measurements, the development of improved models for use in the computation of both external and internal exposures, and efforts to make greater and more direct use of both the whole body counter measurement data and of individual residence histories.

There are concerns about the possibility of confounding exposures that may lead to biased risk estimates. In particular, some residents of the upper Techa (where the doses are the highest) had additional exposures as a result of the Kyshtym accident [7] in 1957. Another potential source of

confounding exposure is the large gaseous releases of ^{131}I and other radionuclides through the radiochemical plant stacks at Mayak. The distribution of medical x-ray exposures has not been investigated and it is possible that villagers on the upper reaches of the Techa have more medical exposures at the URCRM clinic than people living on the lower portions of the Techa. There is also a possibility of chemical exposures due to the Mayak releases or from agricultural chemicals.

Future plans

Analyses of solid cancer and leukemia mortality risks in the ETRC using the extended catchment area and the TRDS-2000 should be completed within the next year. These analyses will include basic risk estimates (dose response estimation) and some examination of effect modifying factors such as gender, ethnicity, and age at first exposure. They will also include investigation of temporal patterns of the excess risks. Site-specific cancer risks will also be evaluated for sites with adequate numbers of excess cases, though this is likely to be complicated by the relatively small numbers of radiation-associated cases for specific types of cancer. In addition, we will investigate the influence of uncertainties in dose estimates and limitations of the follow-up data on risk estimates in this cohort.

The dosimetry system will be refined and follow-up improved in order to provide more precise risk estimates. To date, ETRC solid cancer risk estimates have been based solely on mortality data. Some leukemia risk estimates have been based on morbidity data since virtually all leukemia cases among ETRC members still resident in the southern Urals are believed to have been examined and treated at URCRM. Cancer incidence data for the period after 1956 is being obtained for ETRC members residing in Chelyabinsk oblast [8]. Analyses of these data will begin in the near future.

References

1.Kossenko MM, Degteva MO (1994) Cancer mortality and radiation risk evaluation for the Techa River population. Sci Total Environ 142:73-89

2.Kossenko MM, Degteva MO, Vyushkova OV, Preston DL, Mabuchi K, Kozheurov VP (1997) Issues in the comparison of risk estimates for the population in the Techa River region and atomic bomb survivors. Radiat Res 148:54-63

3.Kozheurov VP (1994) SICH-9.1-a unique whole-body counting system for measuring SR-90 via bremsstrahlung. The main results from a long-term investigation of the Techa River population. Sci Total Environ 142:37-48

4.Degteva MO, Vorobiova MI, Kozheurov VP, Tolstykh EI, Anspaugh LR, Napier BA (2000) Dose reconstruction system for the exposed population living along the Techa River. Health Phys 78:542-554

5.Degteva MO, Shagina NB, Tolstykh EI, Vorobiova MI, Napier BA, Anspaugh LR (2002) Studies on the Techa river populations: Dosimetry. Radiat Environ Biophys 41: (this issue)

6.Kossenko MM (1996) Cancer mortality among Techa River residents and their offspring. Health Phys 71:77-82

7.Akleyev AV, Lyubchansky ER (1994) Environmental and medical effects of nuclear weapon production in the southern Urals. Sci Total Environ 142:1-8

8.Kossenko MM, Hoffman DA, Thomas TL (2000) Stochastic effects of environmental radiation exposure in populations living near the Mayak Industrial Association: preliminary report on study of cancer morbidity. Health Phys 79:55-62